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DOMINION OF CANADA—DEPARTMENT OF AGRICULTURE

APPLE NUTRITION

By

M. B. DAVIS *and* H. HILL

Illustrations by Arthur Kellett

DIVISION OF HORTICULTURE

EXPERIMENTAL FARMS
SERVICE

M. B. DAVIS
DOMINION HORTICULTURIST

Published by authority of the Hon. JAMES G. GARDINER, Minister of Agriculture,
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TABLE OF CONTENTS

APPLE NUTRITION

This bulletin is published in an effort to educate growers of apples to use the symptoms expressed by their trees as a guide to their fertilizer program. An attempt is made to describe the function and needs of the various fertilizer elements, and, with the aid of colour plates, some of the more common nutritional disturbances.

To obtain the most profitable returns from the use of any fertilizer, it is of the utmost necessity that the grower be in a position to employ sound judgment based on a knowledge of fundamental principles; a properly interpreted soil analysis; a symptomatic diagnosis or a combination of both. Although general recommendations are of necessity given, they cannot hope to meet the needs of even the majority of cases. If the nutrition of the apple tree could be considered separately from the various soil and environmental conditions a definite formula could be given for its feeding, but trees are grown in soils of widely variable physical and chemical composition, each different soil condition having an influence on availability of nutrients to the tree.

The availability of nutrients in a given soil is itself affected by variations of climatic factors, especially rainfall.

NUTRIENT REQUIREMENTS OF APPLE TREES

As a beginning one should appreciate the requirements of an apple tree and have some understanding of the role of each element involved in its feeding.

Nitrogen

This element is absolutely essential for the growth of a tree, and is probably the most generally required element of all. It is doubtful if any but organic soils can maintain a high state of fertility without frequent applications of nitrogen in some form or other. Since too much nitrogren at one time is not a good thing, and as it may frequently be lost from a soil by leaching and by bacterial action, it is not desirable to make heavy spasmodic applications. Smaller amounts applied annually are preferable.

Sources of Nitrogen.—Manure, any decayed organic matter, sulphate of ammonia, nitrate of soda, and cyanamide are the more common carriers of this element.

Organic nitrogen, such as is found in manure or other vegetable material, is generally more slowly available than in the mineral form, but where a quick response is not essential it is quite satisfactory.

In regard to inorganic sources of nitrogen, it is preferable to employ sulphate of ammonia on soils that are alkaline; on acid soils the other forms are quite satisfactory. Generally, a combination of organic and inorganic sources is best and this is accomplished by the grass mulch system of orcharding discussed later.

Potassium

This element is just as essential as nitrogen. It is necessary for the manufacture and translocation of the sugars and starches of the leaves and fruit, and trees growing on soils low in this element are liable to produce poorly coloured fruit with low sugar content. Potassium is particularly necessary for a proper

root development and is a factor in controlling both the uptake and loss of water by the plant. The apple fruit itself contains a considerable quantity of potassium. Every barrel of apples contains about four ounces of potassium or the equivalent of half a pound of muriate of potash, so that a tree producing a crop of four barrels would utilize two pounds of muriate of potash in the fruit alone, without making any allowance for the potassium used to make roots, trunk, limbs and leaves. It is thus easy to see that it would take a wonderful soil to provide indefinitely the required amounts of this element.

Sources of Potassium.—Manure, muriate of potash, sulphate of potash and unleached wood ashes all supply potassium. On soils low in potassium it is generally better to employ the mineral carriers; this will be better understood after reading the section on balance.

Phosphorus

This is the next most important element in apple nutrition. While large amounts of this element are not required, it is extremely important. An apple tree grown in pure sand will die more quickly from phosphorus starvation than from the lack of other elements, but a very small amount will maintain life and production. It is essential in the manufacture of the proteins produced by the leaves and fruit and like most plant foods is necessary in the production of roots.

Sources of Phosphorus.—Bonemeal (very slowly available); superphosphate (sometimes called acid phosphate); ammophos. The latter contains both nitrogen and phosphorus, but is not generally employed in orchards.

Calcium

Lime or calcium is just as essential in plant growth as any of the other elements, but probably is less often required in the fertilizer mixture. This is due to the fact that in a great many soils there are large amounts of calcium as parent material. The ash of an apple contains a large percentage of calcium, but since most sprays contain a considerable amount of lime it is doubtful if further applications are called for except in extreme cases of soil acidity where liming may be recommended. Excess of lime is a more common trouble, often being associated with the occurrence of "lime induced chlorosis," due to a deficiency of iron or manganese within the plant (Illustration 16) and drought spot, internal cork or corky core, due to a deficiency of boron (Illustrations 8, 9, 10, 12). Intake of potassium may also be interfered with as discussed under lime-potassium balance on page 10.

Sources of Calcium.—Gypsum (calcium sulphate), although supplying lime for plant use is of no value for the correction of soil acidity; marl or shell marl; ground or crushed limestone. (There are two kinds of limestone, calcitic and magnesian (dolomite). The former consists mainly of carbonate of lime, the latter of carbonates of both lime and magnesia.) Quicklime and slaked lime are employed less frequently, being more expensive than ground limestone and more difficult to handle.

Magnesium

This element is necessary for the development of the chlorophyll or green colouring material of the leaf. It is only in recent years that it has been found necessary of consideration in the fertilizer program. Several orchard areas in Canada have shown definite need for applications of magnesium and it is fully expected that this need will increase in future years.

Sources of Magnesium.—Dolomitic limestone (slowly available source of both calcium and magnesium); magnesium sulphate; sulphate of potash magnesia (containing both potassium and magnesium); kieserite; seawater magnesium oxide; calcined dolomite.

Boron

Boron is one of the so-called minor or trace elements and is only required in very small amounts. It is absolutely essential for healthy development of many species of plants, as in its complete absence plants suffer from various disorders and die.

Sources of Boron.—Boric acid; borax (sodium tetraborate). Both these sources of boron have given satisfactory results; but the latter is cheaper.

Iron

Iron is another minor element essential for the development of the green colouring matter in leaves, without which the leaf cannot function efficiently. It is generally present in all soils but may become unavailable to the tree, as will be explained under the section on balanced nutrition.

Sources of Iron.—Ferrous sulphate; ferric citrate; ferrous tartrate; ferric chloride.

Manganese

This is another minor or trace element related to chlorophyll formation and essential to the growth of plants. Very few definite examples of the lack of this element for apple trees are available. Manganese deficiency is most commonly encountered in alkaline soils.

Sources of Manganese.—Manganese sulphate.

Zinc

Zinc is a minor element necessary for plant life, but so far no definite cases of its deficiency in Canadian soils have been noticed. In the western states it has been found a remedy for certain cases of little leaf and rosette of apple trees.

Sources of Zinc.—Zinc sulphate.

BALANCED NUTRITION ESSENTIAL

The foregoing paragraphs have introduced the reader to the known important major and minor elements necessary for the production of a satisfactory crop of apples. With all these available in sufficient but not excessive amounts, production of maximum crops is not a difficult procedure. With any one of them absent or available in insufficient quantity serious nutritional difficulties may arise. Even excess amounts of any of these elements may give rise to serious disorders. Just what is a sufficient amount, or what constitutes an excess, cannot be definitely stated with mathematical precision since relative amounts are often of more importance than the actual amount available. Thus the relationship or balance between certain elements is of paramount importance and this factor must be fully appreciated. Whether this correct relationship or balance between the different elements exists in a given soil depends on several factors such as the original soil content; the cultural treatment the soil has received over a period of years and the fertilizer program which has been practised. Even starting with a perfectly balanced soil, man can and often has destroyed its fertility by faulty manipulation such as:

(*a*) Continuous clean cultivation, which brings about a depletion of the organic matter and a lowering of the nitrogen content and which may also, due to the lower organic matter, render unavailable certain of the mineral elements.

(*b*) The continuous use of a single element fertilizer, which tends to build up this particular element to an excessive amount and which at the same time encourages the plant to draw more heavily on the soil for

the other elements not applied. In this manner there is a tendency to deplete the soil and upset the original nutritional balance. Some of these balances are fairly well understood and will bear examination.

Nitrogen-potassium balance

The relationship between nitrogen and potassium is very important. The larger the amount of nitrogen available up to a certain point, the greater growth the plant is able to make. The more it grows the greater is the demand from the soil for all other elements, but of these elements potassium seems to be in particular demand. Frequently a soil may have sufficient available potassium to satisfy a tree when grown under a certain nitrogen level, but if the nitrogen is raised beyond that level a deficiency of potassium may result and can only be corrected by further additions of that element. The amount of potassium required, therefore, is dependent to a large extent on the amount of available nitrogen. Thus the continuous use of a nitrogen-only fertilizer or a fertilizer high in nitrogen and low in potassium could easily lead to a deficient potassium condition.

Phosphorus-potassium balance

Under commercial conditions the possibility of an excess of phosphorus is not so likely as an excess of nitrogen, but there are recorded instances of where excessively high phosphorus has brought about a deficient potassium condition. Since apple trees do not feed heavily on this element, the continuous use of large quantities of phosphoric fertilizers without the application of potassium is not to be recommended.

Lime-potassium balance

On soils excessively high in lime the intake of potassium may be interfered with, so that on soils naturally high in lime it may be necessary to pay special attention to the available potassium supply, and the continued use of lime in the absence of potash fertilizers is not to be considered as sound practice.

Lime-iron-manganese balance

Another important balance is the relation between lime and the availability of both iron and manganese. On high lime soils it is not uncommon to find apple trees suffering from a deficiency of either or both of these minor elements.

Potassium-magnesium balance

Generally the accumulation of large amounts of potassium in a soil does not do any harm, but it is possible on low magnesium soils to aggravate a magnesium deficiency by the continued use of potash without an adequate amount of some form of magnesium.

SYMPTOMATIC DIAGNOSIS

The following colour plates and black and white illustrations present material useful in the diagnosis of certain nutritional deficiencies.

Nitrogen deficiency

A deficiency of nitrogen is very quickly reflected in:—

(*a*) Smaller leaves.

(*b*) Shorter terminal growth of a spindly nature.

(*c*) Light brown or bright red bark.

(*d*) A paling of the foliage to pale green, greenish yellow or even yellow in severe cases (Illustration 1, fig. 6). Note that the leaf is not scorched or burned in any way; neither is it mottled, nor does it

possess any amount of green tissue adjacent to the veins. It is merely a uniform pale yellowish green. Fortunately a tree suffering from low nitrogen can easily and quickly be corrected by the application of some quickly available nitrogenous fertilizer.

Nitrogen excess

(*a*) With an over abundance of nitrogen, trees are over vegetative, producing an excessive amount of growth of a succulent nature; too many water sprouts develop.

(*b*) The leaves are large, at first a very dark green colour (Illustration 2, fig. 2). Later such leaves may show a puckering at the tip, followed by a browning or burning (Illustration 1, fig. 7). Unless there is a commensurate supply of available potassium an induced deficiency of this element may occur causing marginal scorching of the leaves (Illustration 1, fig. 5, Illustration 3, all figures).

(*c*) The fruit is poorly coloured.

Corrective Measures: Drastically reduce or omit the application of nitrogenous fertilizers until the foliage becomes medium green in colour and growth is adequate but not excessive.

Up to a certain point the effect of excess available nitrogen may be overcome by increasing the available supply of potassium. While reducing or omitting nitrogenous fertilizers increase the application of muriate of potash to 250 to 300 pounds per acre to mature trees until foliage symptoms of potassium deficiency are corrected.

Potassium deficiency

A deficiency of potassium is probably one of the most common and most serious disorders in Canadian orchards and is fairly easily recognized by foliage symptoms.

Foliage symptoms.—Symptoms first appear on the lower leaves of current growth progressing upwards as the deficiency advances. Except in cases of rather severe potassium deficiency the terminal leaves may remain normal. Before any scorching appears the leaf may merely present a certain amount of olive-brown discoloration, generally confined to the margins as in Illustration 3, fig. 1. A little later in the season some of these leaves will show an orange or reddish-brown margin as in Illustration 3, fig. 2, presenting a combination of a brown or scorched margin with a tone of olive-brown discoloration next to it.

Still later, the scorching becomes more pronounced as in Illustration 3, figs. 3 and 4, with the scorched areas presenting a reddish-brown appearance and the olive-brown discoloration still remaining next to it.

Finally the scorched tissue changes from orange or reddish-brown to greyish-brown with a distinctive ashy grey along the margins, sometimes extending more or less into the body of the leaf (Illustration 1, fig. 5). The leaves become hard and brittle and the margins of affected leaves become broken and ragged (Illustration 4).

Since there is a possibility of confusing magnesium deficiency scorching with potassium deficiency scorching, follow carefully the explanation under magnesium deficiency symptoms.

Corrective Measures.—Since an abundant supply of available nitrogen aggravates a deficiency of potassium, nitrogen applications should be omitted or materially reduced until the deficiency is corrected.

Soil applications of sulphate or muriate of potash should be applied at the rate of 200 to 500 pounds per acre to mature trees, according to the severity of the disorder.

FIGS. 1, 2 and 3 portray different expressions of phosphorus-deficient conditions. FIG. 4—Leaf from tree deficient in phosphorus and potassium. Note reddish-brown margins resemble discoloration in phosphorus-deficient leaf FIG. 1, while tip of leaf has greyish scorching typical of potassium deficiency as seen in FIG. 5. FIG. 5—This stage of potassium deficiency is subsequent to FIGS. 1 to 4, Illustration 3, and precedes the final broken and ragged appearance shown in Illustration 4. FIG. 6—Uniform pale yellowish-green leaf, typical of nitrogen deficiency. FIG. 7—Blistering and burning of the leaf apex due to excessive nitrogen. FIG. 8—Burnt and perforated area due to calcium deficiency.

ILLUSTRATION 2

FIG. 1—Normal green coloration. FIG. 2—Darker than normal green due to excess nitrogen.

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ILLUSTRATION 3

FIG. 1—Early stage of potassium deficiency showing olive-brown discoloration on the margins. FIG. 2—Symptoms more advanced showing brownish-orange scorching. FIGS. 3 and 4—Discoloration has extended further into body of the leaf and scorched areas have become enlarged and reddish brown.

Illustration 4

A shoot from a tree in an advanced stage of potassium deficiency. The leaves are hard and brittle, the margins broken and ragged with a distinctive cigar-ash grey colour along the margins and extending into the body of the leaf.

Phosphorus deficiency

A lack of phosphorus expresses itself in:

(*a*) Delayed bud break in the spring.

(*b*) Fewer leaf buds.

(*c*) Abnormally small leaves.

(*d*) Foliage dull dark green, lacking lustre; later in the season taking on a bronzed appearance except in the region of the midrib, or the midrib and secondary veins. Illustration 1, figs. 1, 2 and 3 portray different expressions of phosphorus deficient conditions. Maturity and abscission of leaves occurs early.

(*e*) Growth is limited and slender.

Corrective Measures.—Annual application of 175 to 200 pounds of 20 per cent superphosphate will maintain a satisfactory level of available phosphorus in the average orchard soil. If an actual deficiency exists it may be necessary to increase this amount until deficiency symptoms disappear.

Calcium deficiency

No actual cases of calcium starvation of apple trees in the field have been encountered.

Pot trees grown in sandstone and not supplied with calcium had the following characteristics:

Foliage Symptoms.—For a time rather large and luxuriant foliage is produced. Later the leaves become normal to slightly small in size. The foliage becomes somewhat light green and a marked rolling of the leaves occurs, exposing the margins of the undersurfaces. The margins of the undersurfaces are often discoloured, reddish purple with the veins in the same area similarly affected. The margins become burned changing from medium to dark brown or blackish brown. Similar patches sometimes occur in the centre of the leaf (Illustration 1, fig. 8).

Corrective Measures.—Calcium deficiency will probably occur only on very acid soils with a pH below 5·0 to 5·5. A soil reaction from pH 6·0 to 6·5 appears to be suitable for apple trees. A soil reaction below pH 5·5 will likely be unfavourable to the growth of many cover crops or permanent sods.

A liming material such as ground limestone will raise the pH or correct high acidity and at the same time serve as a source of calcium. Since magnesium deficiency is also likely to occur on such acid soils, a dolomitic or magnesium ground limestone is preferable to a calcitic limestone. The lime should be spread uniformly and a more favourable response will be secured if the lime is ploughed into the soil. The rate of application will vary from one-half to two tons per acre, according to the degree of soil acidity.

Magnesium deficiency

Leaves showing the effect of magnesium deficiency may at first glance be confused with those suffering from potassium deficiency, but a careful examination will reveal certain distinguishing differences (Illustration 5).

Foliage Symptoms.—Foliage symptoms of magnesium deficiency are not generally apparent until the latter part of July. Up until this time growth is not appreciably retarded, the leaves are normal in colour and somewhat large in size. The symptoms first appear at the base of the current year's growth and progress upwards. In some varieties such as the Melba the most prominent foliage symptom is a yellowing, beginning around the leaf margins and progressing inwards towards the mid-rib. The veins and tissue adjoining the veins remain green, producing an effect of green and yellow bands (Illustration 5, fig. 1). The yellowed bands of tissue ultimately die and become brown in colour (Illustration

ILLUSTRATION 5

Various expressions of magnesium deficiency, FIG. 1 depicting a commonly encountered early stage prior to burning, FIGS. 2 to 5 variously advanced stages.

Illustration 6

Rolling of leaves, accompanied by burning, due to magnesium deficiency.

Illustration 7

Defoliation following symptoms shown in Fig. 2, a characteristic result of severe magnesium deficiency.

5, figs. 2, 4 and 5). On some varieties such as Fameuse and McIntosh similarly affected leaves may occur although as often as not marginal or central intervenal blotches of dead brown tissue appear without any previous or accompanying bands of yellow tissue (Illustration 5, figs. 2, 4 and 5). When patches of dead tissue occur without any previous or accompanying yellow bands the brown patch is surrounded by a narrow region of light green to yellow green tissue (Illustration 5, fig. 2). This characteristic helps to distinguish between marginal or central breakdown of tissue due to magnesium deficiency and that due to a deficiency of potassium. In the latter case the tissue bordering the brown area is a distinctive olive brown.

By the middle of September dead patches involve a large area of individual leaves (Illustration 5, fig. 5). The leaves become rolled (Illustration 6) and premature defoliation of the older basal leaves takes place (Illustration 7). The fruit is reduced in size and has an immature appearance.

Corrective Measures.—Magnesium deficiency is most likely to occur on strongly acid, light sandy soils subject to leaching. As suggested under "Corrective measures for calcium deficiency" the normal procedure would be to apply magnesium or dolomite limestone to counteract the acidity and at the same time supply magnesium. This should be ploughed into the soil to be effective. Many orchards are in permanent sod or otherwise unsuitable for ploughing. Under these conditions a soluble magnesium compound such as magnesium sulphate may be applied at the rate of two to six pounds per tree depending on the age.

There appears to be considerable difficulty in correcting a magnesium deficiency of apple trees by soil application. Preliminary experiments suggest that incorporating magnesium sulphate in the regular sulphur sprays will be more effective. This should be applied in two cover sprays at the rate of 4 pounds of magnesium sulphate to 40 gallons of spray.

Scorching or burning of leaves due to other causes than nutrient deficiencies or excesses

The distinguishing characteristics between scorching of leaves due to potassium deficiency and scorching due to magnesium deficiency have been pointed out already. Burning or scorching of the leaves may also be caused by spray injury or sudden drought due to extreme temperatures. The following tabulated list of symptoms will serve to distinguish between burning due to these causes and that due to a deficiency of either magnesium or potassium.

Characteristics of magnesium or potassium deficiency scorching of the foliage—

(i) Comparatively slow, gradual development of symptoms during the growing season as previously described.

(ii) Symptoms first appear on the basal leaves of shoots and progress slowly to the upper leaves. Unless the deficiency is very severe the terminal leaves may remain unaffected.

(iii) Leaves do not drop off prematurely in the case of potassium deficiency, while in magnesium deficiency defoliation commences at the base of affected shoots and progresses upwards slowly.

Characteristics of foliage scorching due to spray injury or extreme drought—

(i) Sudden occurrence of burning without any previous symptoms. Portion of leaf not burned is normal in colour; the burnt area being sharply delimited.

(ii) Leaves on any part of the shoot may be burned in the case of spray injury. This burning takes place simultaneously on any affected leaves. There is not any progression of symptoms from leaves on one part

of the shoot to another. In the case of spray injury young terminal leaves may be more severely injured than basal leaves. In the case of trees affected by drought the burning may be rather similar to potassium deficiency scorch and occur from the basal leaves upwards, leaving the terminal leaves unaffected. It can generally be distinguished from potassium deficiency by its sudden occurrence in acute form without any of the preliminary stages previously described.

(iii) If burning is severe enough to cause marked defoliation, leaf fall occurs shortly after the burning is apparent and the defoliation which occurs takes place in the space of two or three days.

Boron Deficiency

It is only in extreme cases of boron deficiency that the growth and foliage of the tree are obviously affected. Long before the deficiency reaches this stage severe disorders of the fruit occur.

In a consideration of physiological disorders of apples which occur on the tree, it is necessary to distinguish between (*a*) those which may be corrected by boron (*b*) those which do not respond to boron treatment.

The troubles which respond to boron are classed as drought-spot or superficial cork, internal cork and corky-core.

Drought-Spot or Superficial Cork.—This type of cork may appear very early in the life of the fruit (Illustration 8). If it occurs somewhat later it first appears as irregular, small to large, light brown, russeted patches on the skin (Illustration 12, fig. 1). These areas later become rugose, darker brown in colour, and as they grow become roughened and cracked (Illustration 12, figs. 5 and 6). The lesions may not extend deeply into the flesh, although in severe cases deep cracks or splits may be formed (Illustrations 12, fig. 2). The disorder has been found on the following varieties either alone or associated with internal cork or corky-core; Fameuse, McIntosh, Wealthy, Stark, Northern Spy, Salome. The disorder exhibits somewhat different symptoms on the variety Ben Davis (Illustration 12, figs. 3 and 4). The initial russeted areas are not present but the fruit is malformed due to irregular depressions dark brown in colour. Internally the lesions are found involving the skin or within 2 mm. of the skin. They are dark brown, usually having a green border.

Internal Cork.—This disorder often appears when the apple is but half grown. Fruits affected at this stage increase but little in size and often drop badly. Affected fruits may be detected on the tree by the blushed or red portion of the apple being somewhat darker in colour than is normal. In some varieties fruit affected early in its growth becomes markedly deformed and knobby (Illustration 13, fig. 3). In other varieties of fruit affected later in their growth, there is no external evidence of the disorder. If the fruit is cut it will show light brown spots of dead cork-like tissue in the region of the core or scattered throughout the flesh (Illustration 9). The Fameuse variety is particularly susceptible to this form of cork.

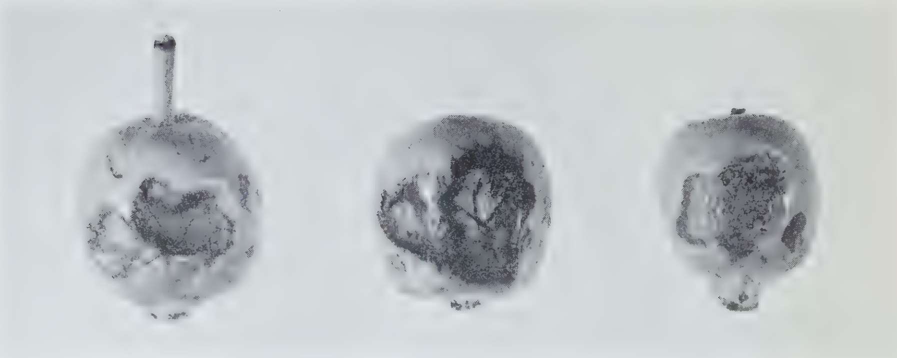
Corky-Core.—In this type of cork the outside of the apple appears perfectly normal. On cutting the fruit transversely light brown patches or a continuous band of brown tissue are found in the core area (Illustration 10). The McIntosh variety is particularly susceptible to this trouble.

Corrective Measures.—All the above troubles have responded to boron treatment and recommendations for control are as follows: Boron should be applied either in the early spring or fall to orchards in any area where cork has been found and where no application of boron has yet been made.

Orchards on acid soils.—Apply 4 ounces of borax to trees up to 10 years of age, 8 ounces to trees from 10 to 20 years of age and 8 to 16 ounces to older trees. If boric acid is used the rates should be two-thirds those mentioned. To apply this small quantity the borax or boric acid may be mixed with several times its volume of dry sand or soil as an aid in spreading.

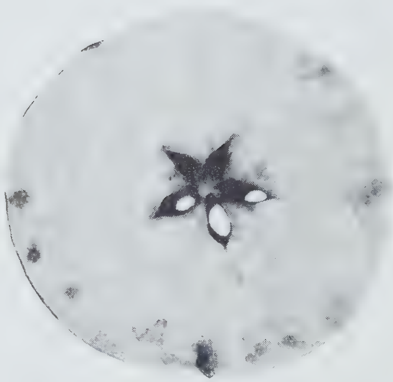
Orchards on alkaline soils.—If the soil is alkaline and high in lime, effective control may not be obtained by applications to the soil in a season when very low soil moisture conditions exist. Under these conditions more effective control may be obtained by incorporating boron with the regular spray. If this is done, two applications should be sufficient, one at the time of the calyx spray and the other the second spray after that, using borax at the rate of $2\frac{1}{2}$ pounds to 100

Illustration 8



Drought-spot affecting young apples (natural size).

Illustration 9



Cross section of an apple affected with internal cork.

Illustration 11

Cross section of an apple affected with Bitter-pit.

Illustration 10

Cross section of an apple affected with corky-core.

FIG. 1.—Initial symptoms of drought-spot or superficial cork affecting McIntosh, occurring as irregular small to large light-brown russeted patches on the skin.

FIG. 2.—Later stages of drought-spot or superficial cork affecting McIntosh. The affected areas have become darker brown, roughened and cracked. Deep cracks or splits have also occurred.

FIGS. 3 and 4.—Drought-spot or superficial cork affecting Ben Davis.

FIG. 5.—Intermediate stage of drought-spot or superficial cork affecting Stark.

FIG. 6.—Intermediate stage of drought-spot or superficial cork affecting Salome.

Illustration 13

Figs. 1 and 2.—External symptoms of typical tree-pit affecting Spy seedling.

Fig. 3.—External symptoms of internal cork affecting Fameuse. Note distorted and knobby appearance.

Fig. 4.—Lenticel spotting on variety Salome.

Fig. 5.—Tree-pit affecting Baxter seedling. The external symptoms are somewhat different from typical tree-pit, in that the normal coloured pits are encircled by a reddish-brown halo of lighter colour.

Fig. 6.—Blotchy-pit affecting Stark.

gallons of the spray mixture. The foregoing recommendations are not to be considered as annual treatments, since there is the possibility of creating toxic concentrations of boron. A single treatment has been found effective for a period of three years. The safest procedure would be to forego further applications until the disorder again makes its appearance.

Foliage and growth symptoms of boron deficiency.—A dying-back of shoots and limbs may also be brought about by a deficiency of boron. In the spring, buds on last year's terminal growth fail to develop, although no browning of the cambium is seen at this stage as is the case where failure of bud break is due to frost injury. As the season advances the affected buds and bark tissue die leaving dead shoots projecting beyond the foliage. Several new shoots may extend beyond the dead tip. The leaves on such shoots may occur in tufts of narrow leaves to which the term rosette has been applied.

Measles.—In certain varieties such as the Delicious, boron deficiency may also cause pimples or blisters on the bark. The affected areas enlarge the following season and small cracks appear in concentric arrangement at the margin of the lesions. Upon cutting through such lesions necrotic areas will be seen in the tissue just underneath the bark or deeper in the wood (Illustrations 14 and 15).

Bitter-Pit and Blotchy-Pit are physiological troubles which have not responded to treatment with boron. These troubles may be confused with cork, but there are distinguishing differences. Pitting does not show up until the fruit is approaching maturity or may not show up until the apples have remained in storage for some time.

Typical Bitter-Pit.—The first symptom is the appearance of slightly discoloured spots, deeper green on green fruit and darker red on red fruit, somewhat sunken or depressed and generally regular in outline. They are likely to be more numerous towards the calyx end (Illustration 13, figs. 1 and 2). When an affected apple is cut, it shows groups of brown, broken down pulp cells in the flesh just under the skin and the affected tissue is generally confined to this area (Illustration 11).

Blotchy-Pit.—In this case the pits are less clearly defined, irregular in outline, larger in size, less sunken, deep green or mottled green and brown blotchy depressions (Illustration 13, fig. 6). Large brown necrotic areas are found in the flesh near the core or close to the surface.

No definite cure has been found for pit disorders, but there is some knowledge available concerning their control. They occur most frequently on late maturing varieties such as Northern Spy, Baldwin, Baxter, etc. Where pit troubles occur the only advice possible at present is to refrain from heavy nitrogen applications and avoid attempts to force tree growth. Adopt a complete fertilizer somewhat lower in nitrogen than ordinarily employed. Avoid excessive pruning in any one season and endeavour to maintain an adequate and continuous moisture supply. On sod orchards heavy mulching has aided in this connection.

Iron and Manganese Deficiency

Foliage symptoms brought about by a deficiency of either of these two elements is sometimes referred to as lime-induced chlorosis and is generally associated with alkaline soils, high in lime. Leaves affected with this type of chlorosis turn a mottled green, sometimes bleaching out to almost pale yellow or white with the veins remaining green for a considerable time (Illustration 16). In some cases manganese deficiency may be differentiated from iron deficiency by the occurrence of dead spots on the chlorotic leaves.

Corrective Measures.—The chlorosis may be due to a lack of movement or translocation of iron within the plant, rather than an actual deficiency in the soil. For this reason soil applications of an iron salt are often ineffective. Placing ferrous sulphate at the rate of one-half pound for each inch of trunk diameter in trenches close to the tree roots has been found more effective than broadcast applications and the application of this material in solution has been found more effective than in the dry state.

Spraying the foliage with a 0·5 per cent solution of ferrous sulphate has also been found effective and is the method suggested for use.

In the case of manganese deficiency a soil application of 30 to 50 pounds per acre of manganese sulphate or spraying the foliage with a 1 per cent solution of manganese sulphate has aided in correcting the trouble.

Zinc deficiency

No instances of zinc deficiency in Canadian apple orchards have yet been recorded.

Illustration 14

Branches of Delicious severely affected with measles. Courtesy Dr. A. B. Groves, Virginia Agricultural Experiment Station, Winchester, Va.

ILLUSTRATION 15

Discoloration of wood in branches of Delicious. Courtesy Dr. A. B. Groves, Virginia Agricultural Experiment Station, Winchester, Va.

Illustration 16

Lime-induced chlorosis—Iron deficiency within the plant due to excessive lime in the soil. Intervenal tissue has turned yellow while veins and tissue immediately joining have remained normal green.

GENERAL FERTILIZER RECOMMENDATIONS

In the foregoing pages an attempt has been made to list and describe the function of the plant food elements an apple tree must absorb from the soil; attention has been drawn to the importance of balance or correct relationship between the available quantities of each element and a number of such fundamental relationships have been discussed; symptoms useful in diagnosing deficiencies and excesses of individual elements have been described by means of colour plates and illustrations and corrective measures given.

Bearing these fundamentals in mind a grower should be in the position to fertilize individual orchards and even individual trees, according to their specific requirements, rather than to rigidly adhere to general fertilizer recommendations which are recommended for orchards on normal soils and are intended to be flexible. Although all the elements mentioned heretofore are necessary for healthy tree growth, it is generally recognized that only nitrogen, phosphorus and potassium require constant replacement in normal orchard soils. Fertilizer consisting of these three elements is known as a " complete fertilizer " and it is recommended that a " complete 9-5-7 fertilizer " should form the basis of orchard fertilizer treatment.

Nitrogen—the growth regulating factor

Since nitrogen of all the elements is the most effective growth regulating factor, it is a good practice to apply nitrogen separately from the minerals. The nitrogen status of a tree can be fairly accurately estimated by foliage colour and amount and quality of shoot growth. A lack of nitrogen is very quickly expressed by the tree in restricted growth and light green foliage (Plate 1, fig. 6) and fortunately this condition can be quickly corrected by the application of a quickly available nitrogenous fertilizer. It is therefore recommended that mineral fertilizers be applied yearly in the amounts suggested and that nitrogen be employed as a balance wheel, using the colour of the foliage and amount and quality of shoot growth to indicate the rates of application. Ordinarily 400 pounds of ammonium sulphate per acre or its equivalent would be considered a moderately heavy application and should only be employed on soils not high in nitrogen. An application of 300 pounds would be a moderate application. If the available mineral content of the soil is high the heavier application would be satisfactory; if low it would doubtless do as much harm as good. Since many orchards are not solidly planted and contain trees of different ages growers often prefer to apply the fertilizer only to the soil area occupied by the tree roots. An application of three-quarters of a pound of ammonium sulphate for each inch of trunk diameter would constitute a moderately heavy application. Orchards in sod generally require heavier applications of quickly available nitrogen than orchards which are cultivated. This is especially true in areas where the mulch material does not decompose rapidly owing to the lack of sustained adequate moisture conditions. Where such conditions prevail it may be necessary to apply a supplemental dressing of ammonium sulphate to the mulch material at the rate of two pounds per tree. To accomplish its purpose nitrogen should be applied early in the spring well in advance of tree growth.

The annual applications of phosphoric acid and potassium to be employed will vary a great deal with the type of soil, so that the following recommendations can only be used as a general guide. Mineral fertilizers may be applied either in the spring or fall, but on cultivated orchards should be applied at a time when it is possible to work the soil immediately.

The following general fertilizer program is suggested

(1) Apply 200 pounds per acre of 20 per cent superphosphate; 125 pounds per acre of either sulphate or muriate of potash; nitrogen as needed in amounts suggested in the preceding paragraph and in the form preferred by the grower. On alkaline soils a nitrogen fertilizer with residual acid reaction such as sulphate of ammonia should be used.

If it is desirable to apply the fertilizer only to the soil area occupied by the tree roots use one-half pound of 20 per cent superphosphate and one-quarter pound of sulphate or muriate of potash for each inch of trunk diameter.

(2) Where it is desired to apply the nitrogen along with the minerals in a complete fertilizer, a 9-5-7 is recommended at the rate of 700 pounds per acre or one and one-half pounds per each inch of trunk diameter. It must be noted that this is to be considered as a maintenance fertilizer on soils in which the plant foods are in a well balanced condition.

(3) Where leaf scorch due to potassium deficiency is present, it would be well to eliminate the nitrogen for a season at least and rely solely upon minerals, applying superphosphate at 200 pounds per acre and sulphate or muriate of potash at 350 to 400 pounds per acre until the deficiency is corrected. On such soils a 4-8-10 should prove a good maintenance fertilizer.

(4) Where manure is available it may be employed successfully. On the average most barnyard manure is about correct in its proportion of nitrogen, phosphorus and potassium for orchard use. Annual applications of 6 to 7 tons per acre should be sufficient to provide the equivalent of 700 to 800 pounds of a 9-5-7. Since the nitrogen in manure is rendered available rather slowly it may be necessary to supplement manure with a quickly available nitrogenous fertilizer early in the spring. Excessive quantities of manure may delay the trees hardening off in the fall, rendering them susceptible to winter injury.

Fertilizer applications are supplementary to good cultural practice

Even though adequate quantities of commercial fertilizers are applied to orchard soils a favourable growth condition cannot be secured unless cultural practice maintains an adequate supply of organic matter and prevents the loss of surface soil by erosion.

There is no factor so important as adequate organic matter for providing the moisture needs of apple trees and as a storehouse of plant food.

Two main systems of cultivation: " clean cultivation with cover crop " and " sod mulch " are practised successfully, the choice depending upon economy of orchard management and the possibility of cultivation without encountering severe soil erosion.

Clean cultivation with cover crop.—This system consists of maintaining a dust mulch in the orchard from early spring until some time early in July. By commencing operations as early as possible in the spring, soil activity at the critical period is augmented and by the maintenance of the dust mulch throughout the major part of the growing season, soil moisture is conserved. The weakness of this system is that the constant cultivation induces the burning up and loss of organic matter so that a cover crop is unable to maintain an adequate supply and additional organic matter must be provided in the form of barnyard manure or like material. Clean cultivation is not suitable for orchards located on steep slopes or hillsides since severe soil erosion is likely to occur unless contour or terraced cultivation is practised.

The use of a cover crop helps maintain the humus content of the soil and by competing with the trees for plant food late in the season aids them in hardening off.

Sod mulch.—This system offers a somewhat cheaper method of maintenance than the clean cultivation and cover crop system and is particularly desirable on rough land or hillside orchards subject to erosion. It also facilitates the development of fruit colour and when sufficient mulch is provided, appears equal if not superior to the dust mulch for moisture conservation.

It is lacking in one essential, namely, nitrate nitrogen when compared with the clean cultivation system. The latter offers an opportunity for the warming up and aeration of the soil in early spring, with a resultant rapid increase in the nitrate nitrogen content of the soil. To overcome this deficiency on the part of the grass mulch it is necessary that somewhat higher quantities of quickly available forms of nitrogen be supplied in the spring, such as sulphate of ammonia or nitrate of soda. On the other hand, the sod mulch system provides greater facility for regulating the nitrogen status of the tree than does clean cultivation. In the latter system the nitrate nitrogen level of the soil may be maintained beyond the period required to ensure adequate growth and fruit production, resulting in poorly coloured fruits and trees susceptible to winter injury.

The grass mulch system must not be confused with the sod orchard where no attempt is made to conserve moisture by maintaining a proper mulch. Orchards now in sod can be quickly changed over to the mulch system by the addition of old hay, straw, or similar material, at the rate of about 100 pounds per tree, spread out as far as the drip of the branches. It will probably be necessary to repeat this mulch application for two or three years, after which the grass cuttings from between the rows should be sufficient to maintain a satisfactory mulch. The space between the rows of trees beyond the drip of the branches may be left in sod and cut two or three times during the growing season, the cuttings being raked up and thrown under the trees.